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-Technical Report-

VICTORY Architecture DoT (Direction of Travel) and Orientation Validation Testing

Prepared By: **Venu Siddapureddy**
Engineer, Vehicle Electronics And Architecture (VEA)
TARDEC/RDECOM
Warren, MI 58397

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U.S. Army Tank Automotive Research, Development, and Engineering Center
Detroit Arsenal
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Vehicle Electronics And
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6501 E. 11 Mile Rd.
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14. ABSTRACT

This document describes a set of validation experiments and will provide verification and validation of the VICTORY 1.0 Architecture DoT & Orientation service(s) specifications. The DoT & Orientation service(s) is implemented according to the standard format specified by the VICTORY 1.0. This service(s) provides DoT & Orientation data anywhere on the VDB (VICTORY Data Bus). The main components and interfaces evaluated on the VDB to verify the implementation included the

- DoT & Orientation data VDM (VICTORY Data Message)
- VDB DoT & Orientation Data Interface
- VDB DoT & Orientation Management Interface

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VICTORY Architecture DoT & Orientation Service Validation Experiments

1.0 Introduction

This document describes a set of validation experiments and will provide verification and validation of the VICTORY 1.0 Architecture DoT (Direction of Travel) & Orientation service specifications. The DoT & Orientation service when implemented correctly and with the standard format specified by the VICTORY 1.0 will provide DoT & Orientation data to the VDB (Victory Data Bus) as shown in Figure 1. The main components and interfaces being evaluated on the VDB (VICTORY Data Bus) include

- DoT & Orientation data VDM (VICTORY Data Message)
- VDB DoT & Orientation Data Interface
- VDB DoT & Orientation Management Interface

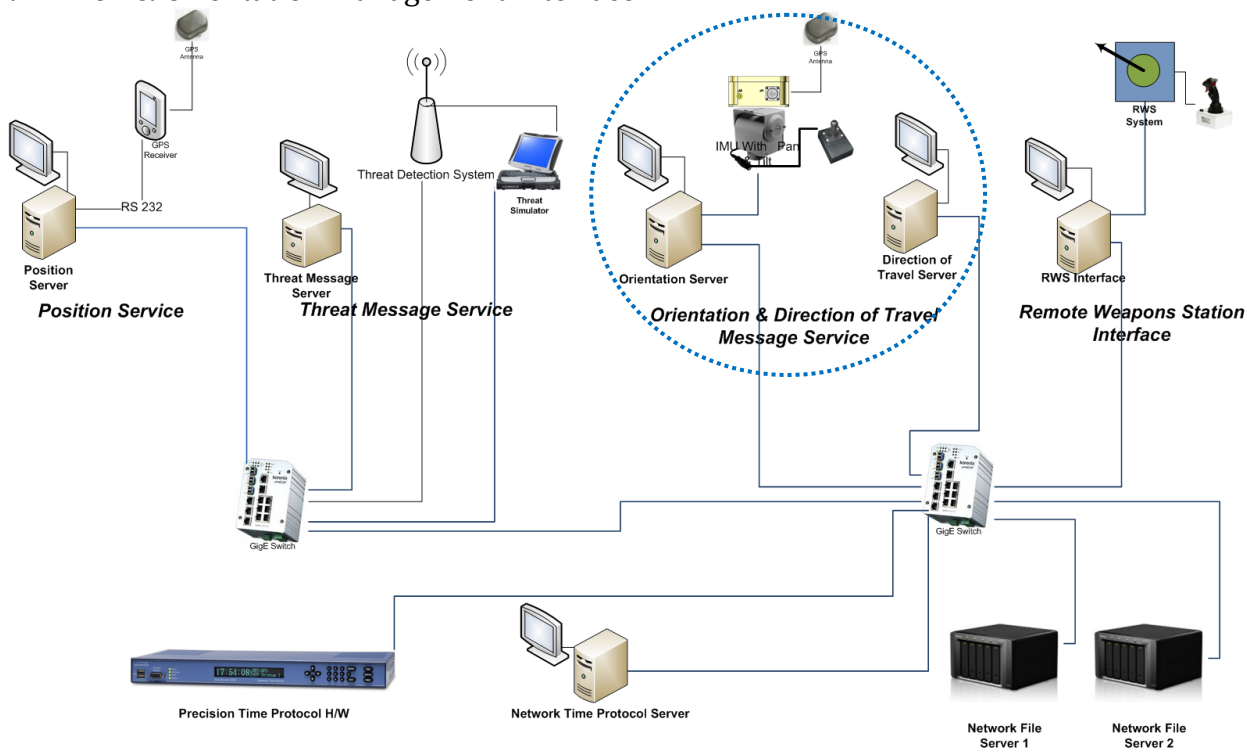


Figure 1: VICTORY Services network as implemented in the VIDS

The experiments will evaluate these interface specifications by integrating software clients and services developed using the specifications, and evaluating the resulting functional behavior and performance. The TARDEC Vehicle Electronics and Architecture (VEA) group executed this set of additional validation experiments, utilizing their VICTORY Interoperability & Development System Integration Laboratory (VIDS)

2.0 Experiment Goals

- Evaluate the completeness and unambiguousness of the individual interface specifications of each included service.
- Investigate the resulting functional performance of reference implementations of the interfaces integrated with representative hardware.

3.0 Experiment Design

The experiments in this set all leverage a common hardware and software design. The Physical/Logical block diagram for testing the DoT & Orientation service is shown in Figure 2. The two test tools used for managing and monitoring the DoT & Orientation VDM's are,

a. Wireshark VDB plug-in
b. DoT & Orientation Service Management Interface

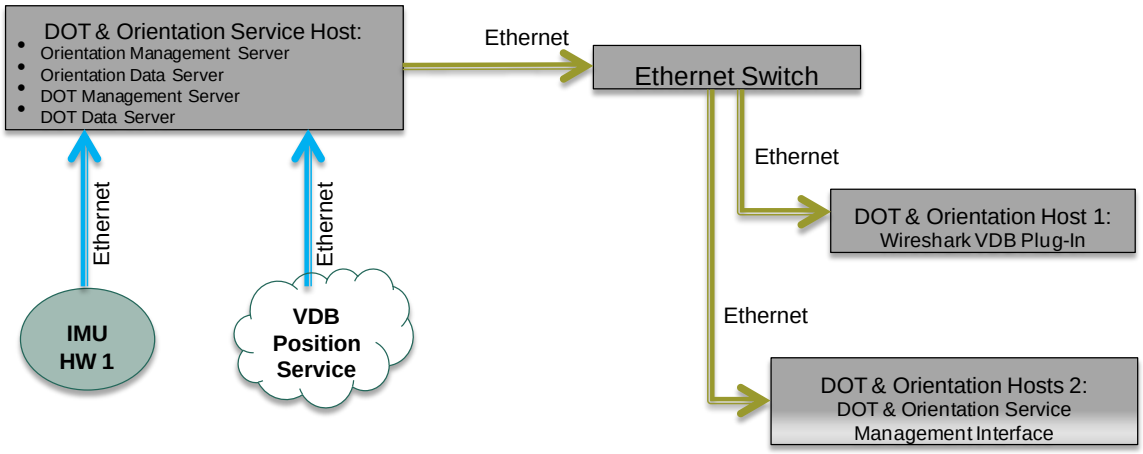


Figure 2: Block Diagram for DoT & Orientation Service Testing.

3.1 Wireshark VDB Plug-in

A custom dissector plug-in for Wireshark version 1.2.8 is developed for the VIDS lab and is used as a tool for testing and monitoring VDM's. This dissector captures UDP VICTORY Data Messages (VDMs) and breaks them down into their specific header and data fields as show in Figure 3. It also provides a filter to look for VDM messages and the ability to log captured VDMs to a formatted text file. Each properly formatted VDM packet contains a "Header" field and a "Data" field, which can be expanded upon as described in the following sections.

The DoT is a derived VDM from the Orientation VDM and the Position VDM. All the static results that are applicable to the Orientation and Position VDM are proxy validation for the DoT VDM. The DoT Static Parameter Results are shown along with the Orientation results, whereas, the dynamic measurements and results are shown separately following the Orientation results in the following sections.

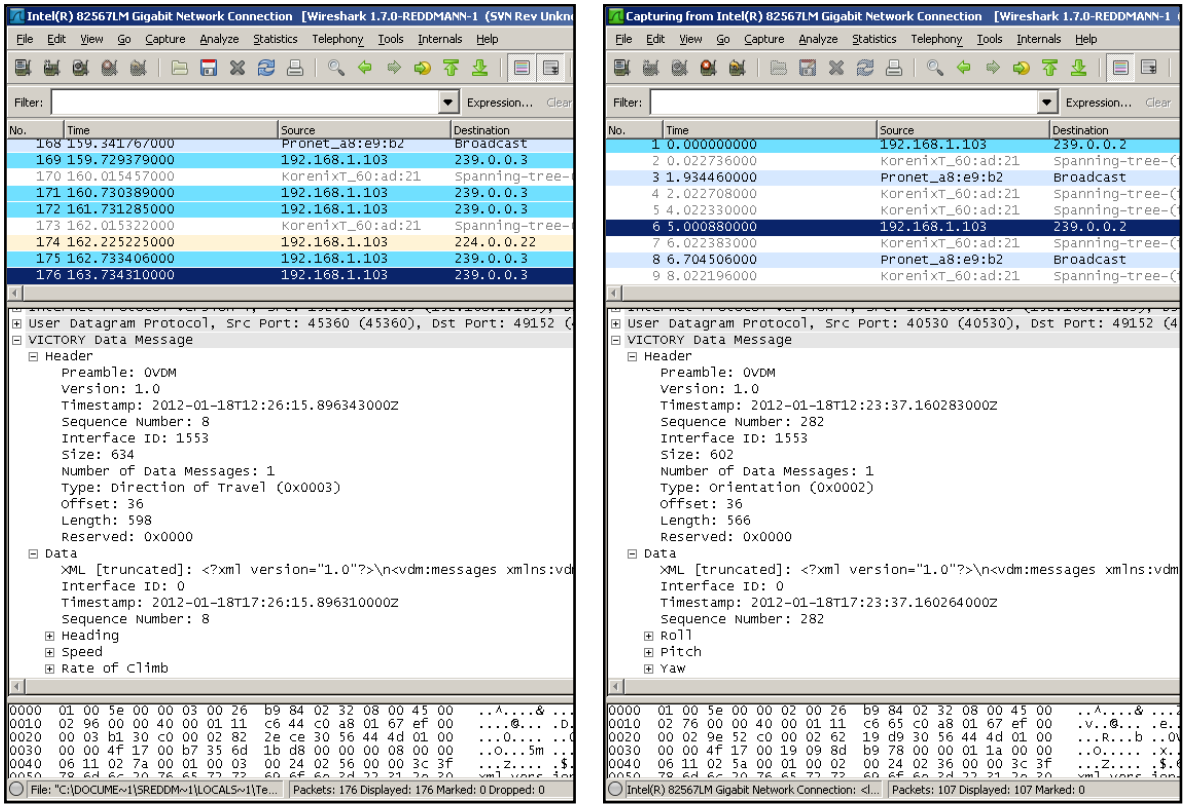


***Figure 3*: Wireshark VDB Plug-in Screen Shot(s) for DoT & Orientation**

3.2 Terminal & GUI Client's for DoT & Orientation VDM Management

In addition to the Wireshark plug-in to view the data and header, two clients are developed to manage the VDM's. One is a command line client and the other is a GUI based client as shown in Figure 4 & Figure 5. Both of these clients perform the same VDM control functionality, i.e. to enable/disable, set data rates, set update period, etc.

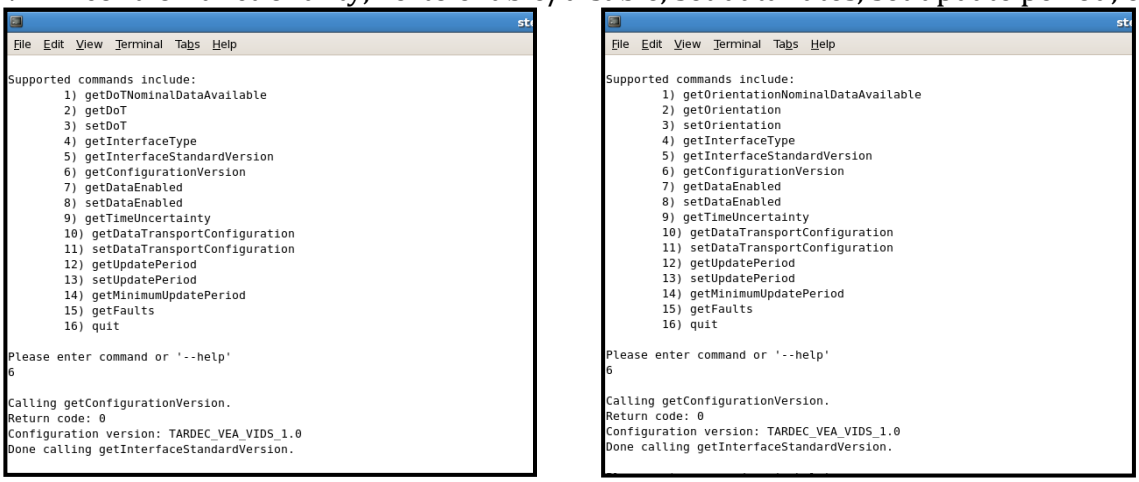


***Figure 4*: Terminal Client for DoT & Orientation VDM Management**

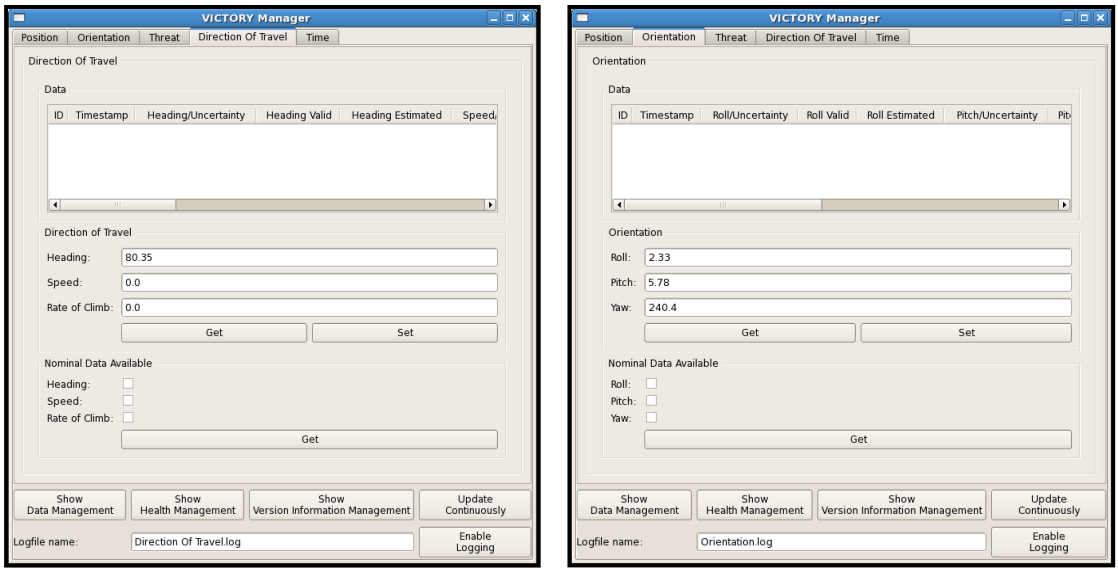


***Figure 5*: GUI Client for DoT & Orientation VDM Management**

4.0 Specifications Evaluated

The VICTORY Architecture 1.0 standards are specified in the Version 1.0 document released on July 29, 2011. The following are the standards that were evaluated

- VICTORY Data Management Interface <10008-20110729, Pro>
- SOAP Compliance and Standards <10001-20110729, Pro>
- Application Layer Data Encoding <20001-20110729, Pro>
- Application Layer Message Encapsulation <20002-20110729, Pro>
- Timestamp Format for Application Layer Data <20004-20110729, Pro >
- DoT & Orientation Data Interface <20007-20110729 & 20008-20110729, Pro>
- DoT & Orientation Management <15001-20110729 & 15002-20110729, Pro>
- DoT & Orientation Interface Complex Types <20012-20110729 & 20013-20110729, Pro>

5.0 Change Proposals Validated

The VICTORY Architecture 1.0 standards are specified in the Version 1.0 document released on July 29, 2011. The following are the change proposals that were validaed

- AIWG CP 003: Direction of Travel Service Data Message Information Content
- AIWG CP 010: Direction of Travel Service Data Message Information Format
- AIWG CP 004: Direction of Travel Service Management Parameters
- AIWG CP 016: Direction of Travel Management/Configuration Interface Specification
- AIWG CP 005: Orientation Service Data Message Information Content
- AIWG CP 012: Orientation Service Data Message Information Format
- AIWG CP 006: Orientation Service Management Parameters
- AIWG CP 017: Orientation Management/Configuration Interface Specification
- AIWG CP 011 - Data Message Format
- AIWG CP 014 - Application Management Core Technology

- AIWG CP 019 - Timestamp Format on the VDB
- AIWG CP 020 - Encapsulation of Data Messages Into Network Payloads

6.0 List of Experiments

This experiment set is composed of the following procedures:

- DoT & Orientation Management Static Parameters
- DoT & Orientation Data Enabled
- DoT & Orientation Data Validity
- Update Period
- Sequence number continuity
- System Resource Usage
- End-to-End Latency

7.0 Procedure 1: DoT & Orientation Management Static Parameters

The DoT & Orientation management interface must maintain a set of static parameters and supply them to the client's request. This procedure will evaluate whether the DoT & Orientation management service can reply to the client's Get() requests on all static parameters. The list of static parameters includes: DoT & Orientation data management specific parameters, version information management specific parameters (interface type, interface standard version and configuration version) and VICTORY data management specific parameters (time uncertainty and minimum update period).

A terminal DoT & Orientation management client described in the previous section 3.0 is used to execute Get() commands on all of the static parameters mentioned above. The results of those Get() commands are recorded and compared to the specification to determine their validity.

Procedure Details

a. Execute a get() command on every static parameter
b. Write down the received values
c. Although the specification doesn't declare the format and range of the static parameters, all static parameters are implicitly assumed to have the same values as the ones in the 'Static Configuration Settings' file. Therefore the received values from the get() request should be compared with the 'Static Configuration Settings' file.

Results

- The received values from the get() request compared with the 'Static Configuration Settings' file are shown in Table 1 below, the values from the get() compare identically with the settings from the 'Static Configuration Settings' file.

Static parameters	Values received by the Orientation client	Values received by the DoT client	Values stored in the 'Static Configuration Settings' file(s) for Orientation/DoT
Interface ID	N/A	N/A	N/A
Source ID list	N/A	N/A	N/A
Interface type	Orientation	DoT	Orientation/DoT
Interface standard version	1.0	1.0	1.0
Configuration Version	TARDEC_VEA_VIDS_ 1.0	TARDEC_VEA_VIDS_1.0	TARDEC_VEA_VIDS_1.0
Geodetic datum	N/A	N/A	N/A
Timestamp uncertainty	0	0	0
Minimum update period	0	0	0
Nominal data available	0, 0, 0	0, 0, 0	0, 0, 0

Table 1: DoT & Orientation service Static Parameters results

8.0 Procedure 2: DoT & Orientation Data Enabled

Data enabled is a parameter that identifies whether the DoT & Orientation data interface is sending out data. This procedure validates whether the DoT & Orientation Management Interface can reply to Get() and Set() requests on data enabled and whether the flow of DoT & Orientation data is properly controlled by the data enabled parameter.
This procedure starts by using a DoT & Orientation management client to send a data enabled Set() command with value of True to the DoT & Orientation management interface. After processing the Set() command, the DoT & Orientation management interface is supposed to enable the flow of DoT & Orientation VDMs, which will be verified using the Wireshark VDM Plug-in described in Section 3.0 with appropriate network filters. Then the DoT & Orientation management client will send a Get() command to the DoT & Orientation management interface for data enabled parameter, with an expected value of True as it was set previously. Next the DoT & Orientation management client will send another Set() command on data enabled with the value of False this time. Wireshark will again verify that there is no longer any DoT & Orientation VDMs sent out. The DoT & Orientation management client will send a data enabled Get() command to ensure that the received value is False. After that the DoT & Orientation management client will set the value of data enabled to True again, and Wireshark will verify that DoT & Orientation VDMs is sent out also. Finally, the DoT & Orientation management client will send out a Get() request to ensure that the value of data enabled is True.

Procedure Details

a. Use the client to set the update period to 1 second
b. Execute a set() command on data enabled property to True

c. Verify on Wireshark that DoT & Orientation data is being sent out periodically for at least 10 update periods
d. Execute a get() command on data enabled property
e. Verify that the received value is 1
f. Execute a set() command on data enabled property to False
g. Verify on Wireshark that DoT & Orientation data stops sending out for a time out of at least 10 update periods
h. Execute a get() command on data enabled property
i. Verify that the received value is 0
j. Set the data enabled property back to True
k. Verify on Wireshark that the DoT & Orientation data is sent out periodically for at least 10 update periods
l. Use the client to request data enabled property and verify that it is 1

Results

- Both Get() and Set() commands work on the data enabled setting.
- When the data enabled property is 1 (True), DoT & Orientation data is sent out periodically.
- When the data enabled property is 0 (False), DoT & Orientation data stops sending out.
- Overall, the outcome matches the expected response.

9.0 Procedure 3: DoT & Orientation Data Validity

Before sending out DoT & Orientation VDMs, the DoT & Orientation data interface must populate all necessary fields of the binary header, formulate the XML payload according to the DoT & Orientation data schema and preserve the integrity of the raw data sampled from any IMU (Inertial Momentum Unit) and the GPS source(s). This procedure will determine the integrity of DoT & Orientation data values and the validity of binary header and XML payload. It will also determine if DoT & Orientation data can be extracted from the DoT & Orientation VDMs in an unambiguous way. In this procedure, raw DoT & Orientation data will be generated using the IMU (Inertial Momentum Unit) and the GPS and fed to the DoT & Orientation data service server's, which in turn generate and broadcast the DoT & Orientation VDMs that will be analyzed and validated as they are captured at the data sinks.

Procedure Details

a. Position VDMs are available on the VDB.
b. Use IMU data input to feed the current orientation.
c. Run Orientation Server to read IMU data and generate Orientation VDM.
d. Run DoT Server to read Orintation and Postion VDM's and generate DoT VDM.
e. Start a client connection(s) to the DoT & Orientation Service Management
f. Execute a set() command on data enabled property to True
g. Run the DoT & Orientation Data Sink(s) for an hour to interpret VDM multicast messages and validate the data
h. The DoT & Orientation Data Sink(s) will write the validation result into a log file

Results

- All messages have valid binary header.
- For the implementation evaluated:
  - The DoT & Orientation values received and extracted from the VDB matched the values that the service encapsulated and sent in the VDM.
  - The DoT & Orientation values sent out by the data service is identical to the raw IMU and GPS values.

10.0 Procedure 4: Update Period

The DoT & Orientation management service must allow dynamic Get() and Set() functions on update period parameter. The DoT & Orientation data service should also arrange transmission delay between each DoT & Orientation VDM in consistence with the update period parameter. The DoT & Orientation management client will set the update period to different values. At each value, DoT & Orientation VDMs will be collected for an hour and analyzed to determine if the update period value is consistent with the transmission period between each DoT & Orientation VDM. Consistency is a subjective criterion in this case.

Procedure Details

a. Use the client to query the DoT & Orientation Management Service for minimum update period
b. Do a set() command to change the update period to its minimum
c. Get() the value and verify it was set correctly
d. Use the DoT & Orientation Data Sink to listen to DoT & Orientation multicast stream and collect DoT & Orientation data for an hour. The DoT & Orientation Data Sink will record the timestamps and differences between successive timestamps into a file.
e. At the same time, use Wireshark with the appropriate capture filter to capture DoT & Orientation data messages
f. Calculate the average of the list of period between successive timestamps from the record file
g. Use Wireshark to generate average packets/sec statistic. Its inverse will be the average update period.
h. Record the value from Wireshark

Results

Wireshark results were captured for a period of 1hour. The average update period for the VDM message set for a 1sec update period is calculated and show below,

Update Period Setting	Average value update for Orientation VDM message from Wireshark	Average value update for DoT VDM message from Wireshark
1 sec	1.0010927 sec	1.0010300 sec

Table 2: DoT & Orientation Service Update Period results

11.0 Procedure 5: Sequence number continuity

The DoT & Orientation data interface must tag each message with a monotonically increasing sequence number before sending it out. To validate the sequence number of DoT & Orientation VDMs, the number of discontinuities will be recorded. DoT & Orientation VDMs will be continuously sent out for an hour, and a DoT & Orientation data sink will analyze the continuity of sequence numbers of all DoT & Orientation VDMs.

Procedure Details

a. Use the client to query for the minimum update period
b. Set the update period to twice the minimum period
c. Perform a get() command to verify that the update period was set correctly
d. Use the DoT & Orientation Data Sink to check if the sequence number increases monotonically
e. Allow DoT & Orientation Data Sink run for one hour and record sequence number discontinuities

Result

Received sequence numbers increases monotonically without any discontinuities.

12.0 Procedure 6: System Resource Usage

This procedure will investigate the computing resources required to interpret DoT & Orientation messages. The recommended metrics for system resource usage is XML processing time.

Procedure Details

a. Start the DoT & Orientation Data Service at a reasonable update rate
b. Use the DoT & Orientation Data Sink to collect values of processing time and memory used during the interpretation and validation of VDM messages
c. Display the results in the log file graphically

Result

The processing time for creating Orientation VDM ranges from 52,000 nsec. to 110,000 nsec. with some sporadic peaks up to 114,000 nsec as shown in Figure 6. The average XML build time is 97,322 nsec and Std Dev of 2,869 nsec.

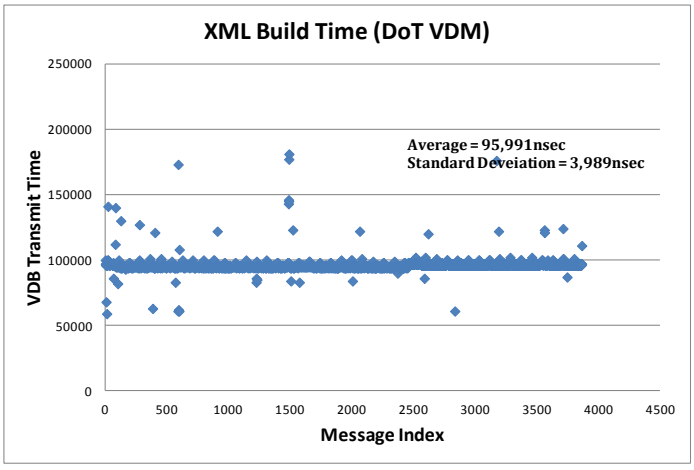


Figure 6: VDM build time for Orientation Service

The processing time for creating Orientation VDM ranges from 52,000 nsec. to 180,000 nsec. with some sporadic peaks up to 180,000 nsec as shown in Figure 6. The average XML build time is 95,991 nsec and Std Dev of 3,989 nsec.

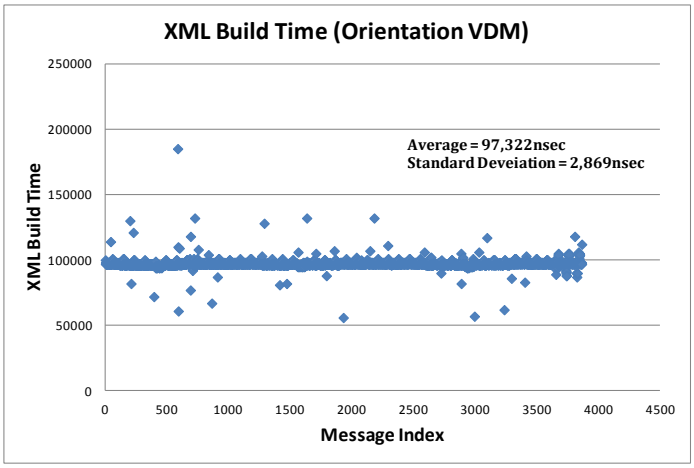


Figure 7: VDM build time for DoT Service

13.0 Procedure 7: End-to-End Latency

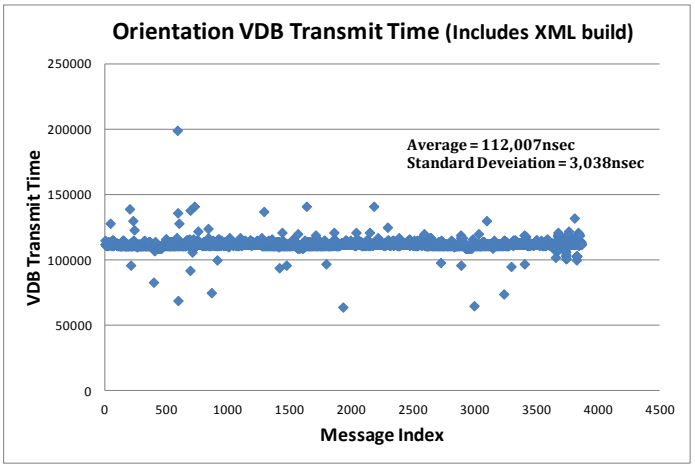
The accuracy of orientation data depends on the latency from the orientation sensor output to the received corresponding update from the Orientation Data Service. This experiment will evaluate this end-to-end latency by measuring the time it takes to transfer an orientation value on the serial port of the sensor into an orientation VDM received by an orientation data sink

Procedure Details

a. Configure Orientation Data Service to sample values over Ethernet connection
b. Start the Orientation Data Service at a specified update period (1 sec for this reference implementation)
c. Start Wiershark Orientation Data Sink. It processes received orientation VDMs, it keeps track of 2 timestamps: one when the VDM was created (within the VDM) and another when the updated VDM is received. The end to end latency of orientation data is calculated by subtracting those 2 timestamps and recorded into a log file.
d. Stop the Orientation Data Sink after about 60 minutes
e. Open the latency log file and display the results graphically
f. The same test is repeated except the DoT service originates the DoT VDMs (The DoT VDM is created using Position VDM and the Orientation VDM available on the VDB). The rest of the procedure remains the similar to the previous test, except the End-to-End Latency is calculated with the origination time at the DoT Sserver.

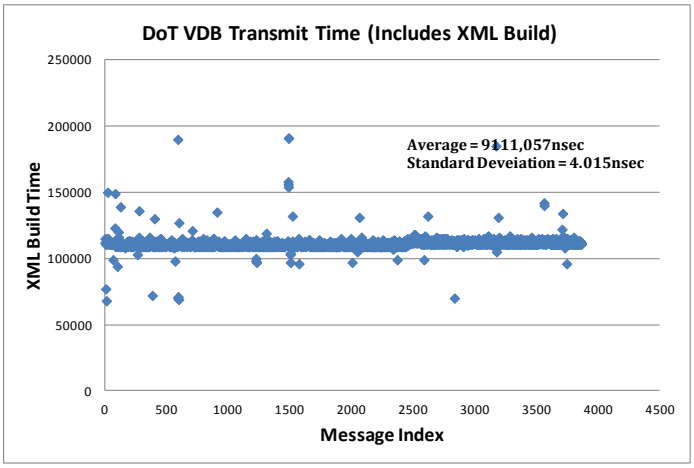
Result:

The results displayed below show the complete DoT & Orientation VDM creation, broadcast and consumption time, i.e. end-to-end latency as shown in Figure 7.



The End-To-End time for creating Orientation VDM, transmitted and sinking the VDM ranges from 60,000 NanoSec. to 105,000 Nano Sec. with some sporadic peaks up to 140,000 Nano Sec and Std Dev of 3,038 nsec.

Figure8: VDM end-to-end time for Orientation Service



The End-To-End time for creating DoT VDM, transmitted and sinking the VDM ranges from 110,000 NanoSec. to 120,000 Nano Sec. with some sporadic peaks up to 150,000 Nano Sec and Std Dev of 4,015 nsec.

Figure 9: VDM end-to-end time for DoT Service

14.0 Conclusion

The experiments performed in the VIDS evaluated the VICTORY Architecture Standards 1.0 interface specifications by integrating software clients and services developed to the specifications, and evaluated the resulting functional behavior and performance. In conclusion, the DoT & Orientation service as specified for the 1.0 standard as implemented in the VIDS is

- Complete and unambiguous of the individual interface specifications of each included service.
- The resulting functional performance of this reference implementation with the representative hardware is adequate to the current development needs of the VICTORY architecture.

The next step in validating the service is determining whether interoperability is achieved when multiple implementers develop to the specifications. These tests will be conducted in the VIDS and the results will be published.

15.0 Open Issues for Future Testing

The testing completed at this stage included only the verification of the standard for the standalone DoT & Orientation Service. Future testing will include interoperability testing, system level testing and end-user testing. To include the services for integrating to end user applications the following tests will be done and the ensuing development will be recommended.

- Notification to the user and the application when the IMU Sensor is down. Recommend mitigation actions to the standard specifications or at the application end.
- Test and report the limit to data broadcast frequency i.e. the update period and limit to the number of connections (open sockets) to the data server when multiple services (Position, DoT & Orientation, Threat, RWS etc.) are implemented on the same server.